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SUBTASK MEMORANDUM

Task: 3.3 How Well Do Measurements Characterize Critical Meteorological Features

Subtask: 4 - Vertical Structure of Relative Humidity

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Summary of 2 meter and 10 meter RH Measurements

NOAA meteorological stations deployed during CRPAQS measured temperature and relative humidity at both 2 meters and 10 meters above the ground surface on the same tower. This provided an opportunity to compare readings made by identical instuments and operating procedures--the only difference being the height of the sensors. Three (3) sites in the SJV were examined: Bakersfield, Fresno, and Chowchilla.

Measurements for Episode 8, which encompassed the period from January 12, to January 24, 2001 were used for this analyses. This episode ranged over an extended period (13 days) and experienced high relative humidity. Figure 1 shows the range of hourly averaged RH over the diurnal cycle at Bakersfield. Fresno and Chowchilla plots were very comparable. Hiumidities were generally the lowest during the daytime in response to warmer ambient temperatures relative to nighttime. Beginning late in the aftenoon, RH increased to values often in the 90-100 percent range from midnight to daybreak. The diameter of the "bubble" is proportional to the RH difference between the 2 meter and 10 meter levels. As can be seen, RH in the lowest 10 meters is relatively constant during day when that layer is well mixed.

The average difference over the diurnal cycle and the range of differences are given in Table 1. The largest differences occur in the early evening as the ground cools averaging 5-7 percent RH at the three sites. During the day, average differences are within 0.5 percent RH—well within the accuracy of the sensors. This agreement attests the relative accuracy of the measurements. RH differences were as high as 15 percent at Chowchilla, 10 percent at Fresno, and 14 percent at Bakersfield. Humidity at the two heights were extremely well correlated. Correlation coefficients were 0.98, 0.99 and 0.99 at Chowchilla, Fresno, and Bakersfield, respectively.

The average temperature difference between the 2- and 10-meter levels at the Bakersfield site is shown on Figure 2. Negative delta temperature is an inverted vertical profile (temperatures warmer at 10 meters relative to 2 meters). Conversely, a positive delta results from an decreasing temperature lapse rate. The average ambient temperature inversions are on the order of 1 ^oC are characteristic of nighttime while the average daytime differences remain 0.5 ^oC or less.

Dew point temperature differences between the two levels are also shown on Figure 2. Dew point is a function of temperature and relative humidity and a more conservative characteristic of an air mass than either. As can be seen from the figure, the average difference in dew point over the diurnal cycle are generally less than 0.2 ^oC. Thus measurements of humidity made at any height on a meteorological tower can be normalized to dew point temperature.

However, PM chemistry model meteorological inputs are relative humidity and ambient temperature not dew point temperature (Robinson, 2003). Robinson provided us with sample output from the DRI model which computes PM10 loading from ambient meteorological and pollutant concentrations. The data shown in Table 2 result from multiple model runs varying only relative humidity while keeping the other input parameters constant. As can be seen, PM levels respond substantially to changes in relative humidity. From this example set of runs, an error of 10 percent (from 95 to 85 percent) results in a 25 percent difference in PM loading.

At issue here is the fact that RH sensors are not mounted and any standard height. For example, the BAAQMD typically mounts the sensor near the top of the 10-meter tower whereas CIMIS mounts all their sensors at 2-meters. Other RH sensors in the network are located on the roof of monitoring trailers or on building rooftops (e.g. Fresno Supersite).

At this time, the CRPAQS data base does not include sensor height above the ground. Moreover, it is not clear what sensor height is appropriate for the model calculations. The best solution would for the models to use a more conservation moisture variable if possible.

Summary of the Angiola Tower RH Measurements

Relative humidity was measured at 5 levels on the 100m Angiola tower--10m, 23m, 43m, 72m, and 98m, thus offered an opportunity to examine the vertical structure of the lower boundary layer. Hourly measurements during December, 2000 were examined.

Figure 3 shows the average diurnal variation in RH at the 5 levels during periods when the atmospheric was stable (i.e. excluding periods when weather frontal systems were affecting the area). Noteworthy characteristics include:

1. From late morning until late in the afternoon, humidity readings tracked very closely at the sensors above 10m. Relative humidity was generally higher at 10m (<10% RH on the average); and
2. At night as the atmosphere stabilizes, a gradient from higher to lower RH develops averaging ~10-13%.

This general RH behavior does vary significantly on a day-to-day basis. For example, on December 6 the fog layer was deep and persistent resulting in near saturation at all levels over the durnal cycle. On December 8, RH was ~100 percent at 10m throughout the diurnal cycle but varied substantially above.

Rawinsonde Measurements

The vertical variation detail in RH measured on the Angiola tower was not in evidence on the rawinsonde measurements. This feature is likely due to a couple of factors. One, the rawinsondes used in this project are primarily used to measure synoptic-scale properties rather than the sub-mesoscale which is the focus this project. As such, the humidity elements are of a relatively high mass thus have a correspondingly long response t ime. Secondly, to measure the detail in the wind and temperature aloft, which is the primary objectives for the rawinsonde observations, balloon ascension rates were scaled down to manufacturer's minimums which may have reduced sensor response times even more.

Table 1.

Episode 8 2M vs 10M RH Measurements

	BSE	**CHOW**	**FAT**
MeanDelta	2.71	2.35	3.05
Delta Range	-2.1 to 13.9	-2.5 to 15.1	-5.7 to 9.6
StdDev	3.30	2.67	1.87
CorrCoef	0.985	0.982	0.993

Hr(PST)	**BSE**	**CHOW**	**FAT**
0	4.1	3.5	3.8
1	3.1	3.5	3.4
2	3.4	2.1	3.4
3	3.5	2.1	3.6
4	3.1	2.1	3.7
5	3.2	1.7	3.3
6	3.6	2.3	3.0
7	3.1	1.7	2.8
8	2.9	1.0	2.0
9	0.3	0.2	1.1
10	-0.4	0.1	1.1
11	-0.5	-0.1	1.2
12	-0.4	0.0	1.2
13	-0.4	0.2	1.4
14	-0.2	0.3	1.5
15	0.1	0.3	2.1
16	1.2	1.6	3.0
17	3.5	4.7	4.3
18	5.6	5.8	4.8
19	5.4	7.1	4.9
20	6.3	5.3	4.9
21	5.3	4.4	4.4
22	4.6	3.3	4.3
23	4.6	3.4	4.1

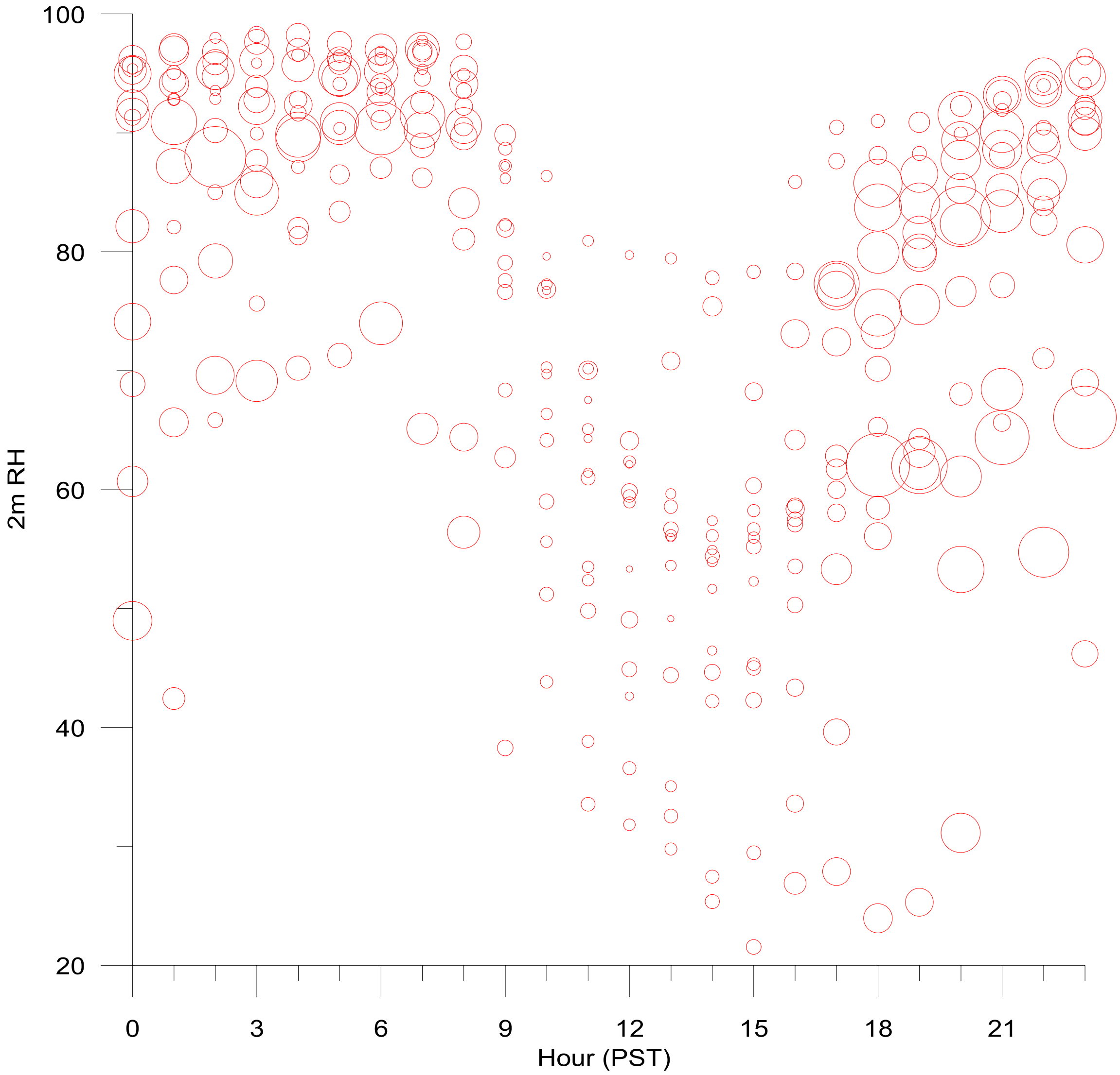
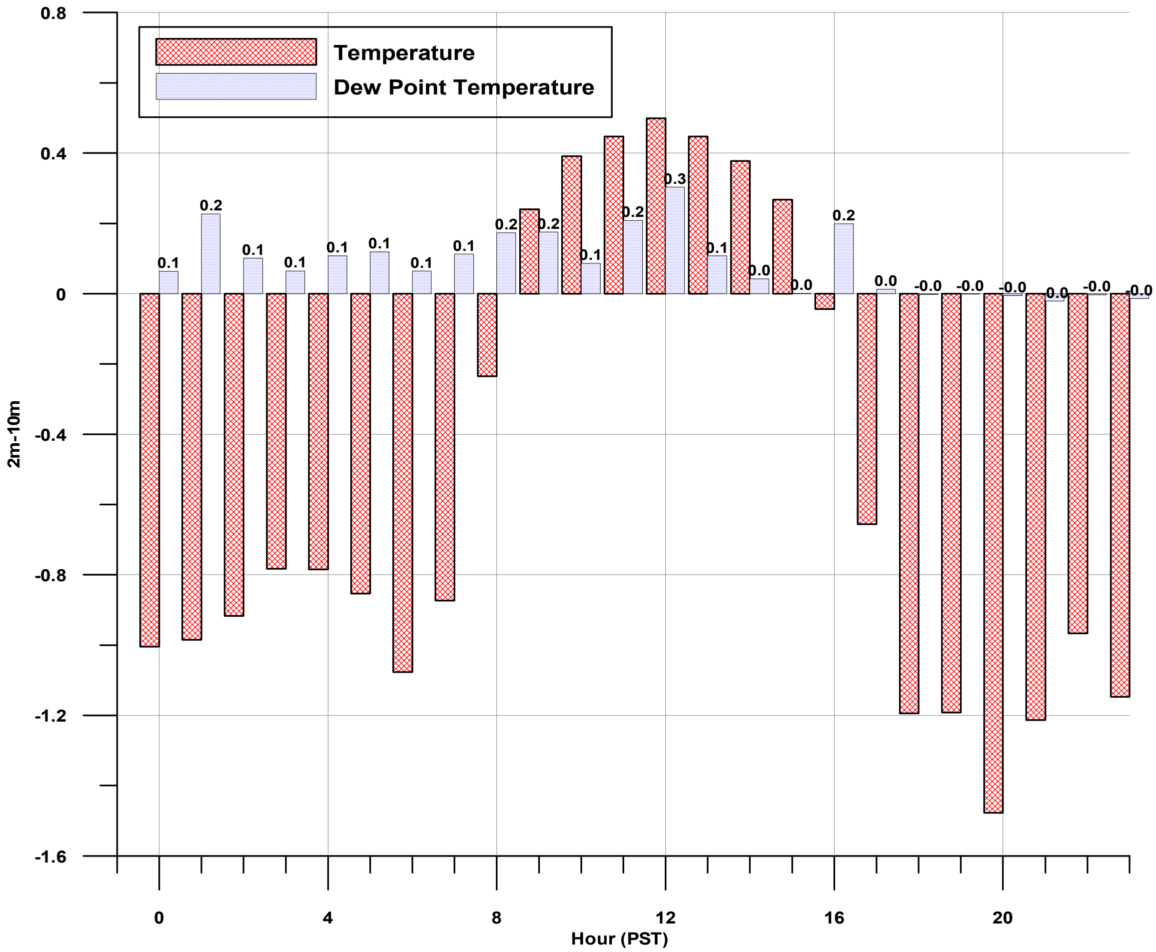


Figure 1. Showing Diurnal RH Readings and Rh Difference Between 2 and 10m Levels At Bakersfield
Bubble diameter is proportional to difference(Note: ranges from -2 to 13%) Episode 8



Showing Temperatue and Dew Point Difference between 2 meter and 10 meter levels
Episode 8 - Average for Episode

Figure 2.

Table 2. GFEMD Model Output

RH (percent)	PM (µg/m3)
95	9.80
94	9.36
93	9.02
92	8.75
91	8.53
90	8.36
85	7.86
80	7.65
75	7.54
70	7.45
65	7.44

Input: T-298˚K, Nitrate = 3, Ammonia = 3, Sulfate = 5, Sodium = 0, Chlorine = 0 (units µg/m3). Source: Robinson, 2003

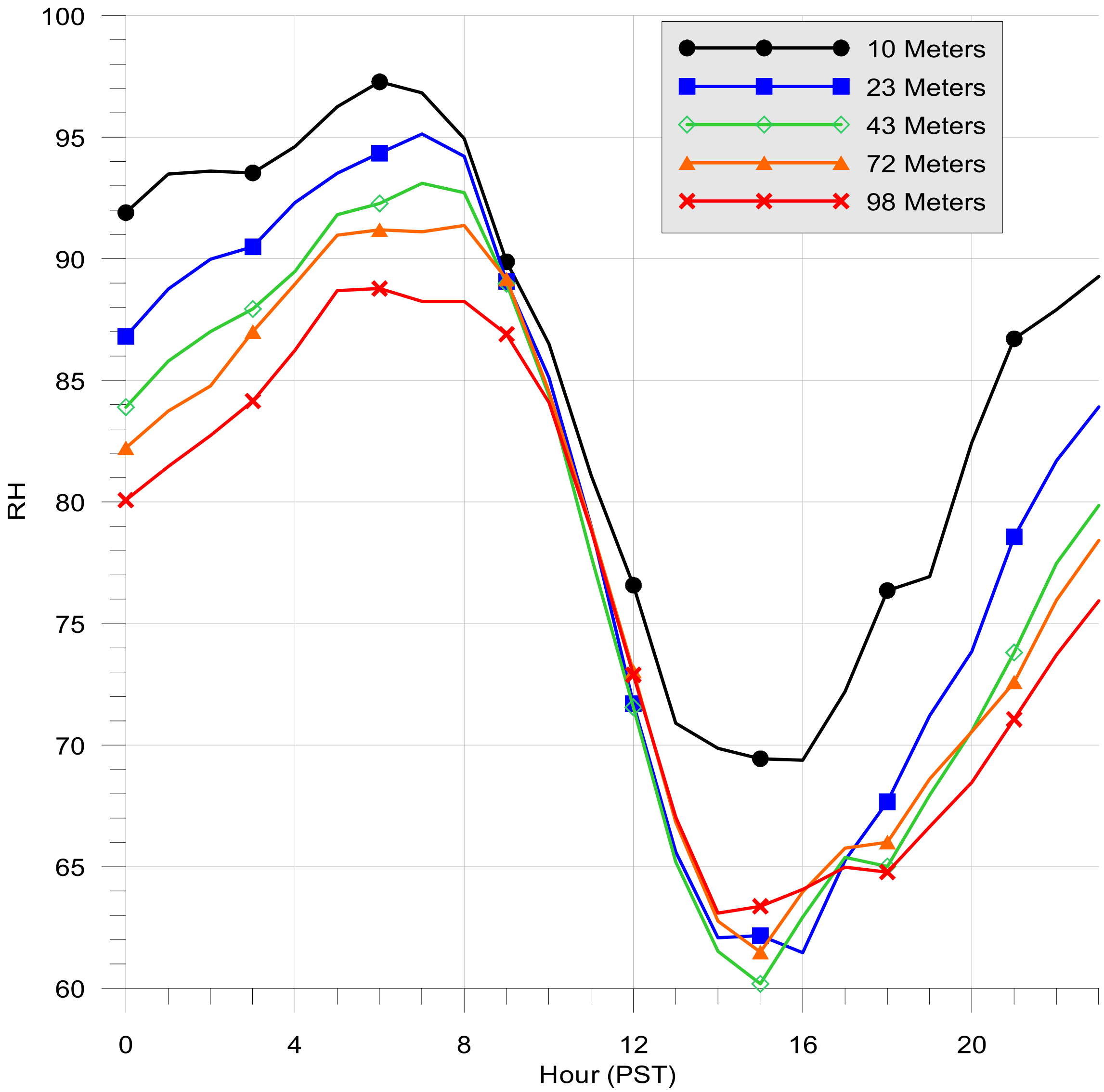


Figure 3. Average Diurnal Relative Humidity Measured on Angiola Tower December 2000, excluding storm events